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PROSPECTS OF USING PREFABRICATED BUILDINGS FOR MEDICAL TECHNOLOGIES

Abstract. In this research paper, an analysis is given of the types of prefabricated buildings and structures (hereinafter PB), from the position of their possible application for a wide range of medical technologies, design features and advantages, and deficiencies in buildings and structures. The article has an overview and research character. The main goal is to determine the most suitable variant of PB for a wide range of medical technologies.

The following issues are considered in the study: the features of using such buildings for a wide range of medical technologies; advantages and disadvantages of each type in terms of design features; the definition of the most suitable type for the construction of medical facilities. Collection of information and analysis leads to the construction of a morphological scheme, which in an accessible form will explain all the conclusions and sum up the results of the research. This will allow using the material for further research in the field of PB, as well as serve as a basis for the application of certain types of buildings for individual medical technologies.

This article is based on our own research, experience and experience of individual firms (both in Russia and abroad), as well as the work of other authors in the field of PB application.

Keywords: pre-fabricated buildings, medical technology, container, STWS, folding section, cleanliness class.

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ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ БЫСТРОВОЗВОДИМЫХ ЗДАНИЙ ДЛЯ МЕДИЦИНСКОЙ ТЕХНОЛОГИИ

Аннотация. В настоящей исследовательской статье приведен анализ типов быстровозводимых зданий и конструкций (далее БВЗ) с позиции их возможного применения для широкого спектра медицинских технологий, конструктивных особенностей и преимуществ, а также недостатков зданий и конструкций. Статья носит обзорно-исследовательский характер. Главная цель — определить наиболее подходящий вариант БВЗ для широкого списка медицинских технологий. При исследовании рассмотрены следующие вопросы: особенности применения таких зданий для широкого спектра медицинских технологий; преимущества и недостатки каждого типа с точки зрения конструктивных особенностей; определение наиболее подходящего типа для строительства медицинских объектов. Сбор информации и анализ приводит к построению морфологической схемы, которая в доступной форме обьяснеет все выводы и подводит итог по проведенному исследованию. Это позволит использовать материал для дальнейших исследований в области БВЗ, а также послужит основанием к применению определенных типов зданий под отдельные медицинские технологии. Данная статья основана на собственных научных изысканиях, наработках и опыте отдельных фирм (как на территории РФ, так и зарубежом), работах других авторов в области применения БВЗ.

Ключевые слова: быстровозводимые здания, медицинская технология, контейнерные, ЛСТК, складывающиеся секции, класс чистоты.

Introduction

PBs of various designs and materials have received a wide use in modern construction. Those installations are often used in emergency situations or in remote areas and have wide range of applications: civil construction, shopping malls, facilities for the needs of defense industry, fast-deployable bases in case of technogenic or natural emergency situations etc. Installation of such facilities and buildings is much more faster and cheaper comparing to traditional methods. According to the utilization experience, those facilities are also suitable for medical complexes and buildings that contain medical technological processes.

The purpose of the present research is to define the types of PB that would be the most suitable for medical institutions.

The research objectives included the following: 1) the analysis of existing types of PB and estimation of their suitability for medical functions; 2) systematization of the information received by applying the method of morphological analysis.

The State of the Subject

Design and study of fast-fabricated buildings in Russia were actively perfomed by various institutions of Rosstroy, Ministry of Defense, MES and other federal and territorial agencies. The goal of introducing of such designs into the construction industry was put at the government level. Thus, in 1972 a decree “About organization and complex supply of lightweight steel constructions of industrial buildings” was adopted, which indicates the following basic advantages of such buildings and facilities: 1) low weight which leads to reduction in labor intensity, installation cost and construction time; 2) high level of pre-fabricated readiness which allows to reduce the capacity of local manufacturing bases and the need in labor (including high-skilled labor) and also to improve the quality of construction; 3) transportability of structures, which leads to reduction in transport costs; 4) possibility of assembly and disassembly of the buildings as well as the redeployment to a new location which allows to use them many times (i. e. inventory); 5) universal applicability, allowing installation of different functional and technological processes in such buildings; 6) universal thermal properties which provides the use of the buildings in different climate regions.

A big contribution into the research of fast-fabricated structures was done by such scientists as: F. F. Tamplon [1], U. S. Slusarenko, A. N. Asaul [2], M. U. Ananyin [3; 4], V. A. Rybakov [5; 6], E. N. Zhmarin [6], F. M. Adam [7–9], etc. A number of researchers has mentioned the use of PB in medical technology: L. P. Kholodova and M. S. Fedorova [4; 10]. However, there was no clear definition, in those works, of suitability of any kind of PB for medical technology. Nevertheless, there is a number of companies in contruction business, that design and fabricate modules, suitable for medicine: “NPO StroyMedService” (Russia), “ADK Modulraum” (Germany), “Containex” (Russia), “Ruukki Vental” (Finland — Russia), etc. Those companies have an extensive experience of using that type of buildings for medical technology: “UMMC Medicina — Department of MRI in Ekaterinburg” (Russia); “Cardiocenter in Chelyabinsk” (Russia); “Center for Neurosurgery in Novosibirsk” (Russia); “Children’s Hospital in Schwäbischal” (Germany); “Superstructure above the hospital in Stuttgart” (Germany); “New hospital in Nyon” (Switzerland); “Addition to the clinic in Vaduz” (Lichtenstein), etc.

Below there is a brief review of the types of PB for a comparative assessment of suitability of buildings for deployment medical technological processes.

PB Types Review

According to GOST 25957–83 “Mobile building and facilities (inventory)” are classified by the following features:

1) the type of mobility: container; assembly-disassembly;
2) the compliance with climatic impacts and stresses;
3) the functional use: industrial; warehouse; auxiliary; living quarters; social.

Analysis of the existing designs has shown that for the organization of medical technology, the structure solutions of PB are the most suitable: 1) from the lightweight steel thin-walled structures (hereafter STWS); 2) frame-panel; 3) of folding sections; 4) frame and awning; 5) container/modular. All the listed types and reviewed below.

Frame system buildings made of STWS

One of the most economical types of construction facilities are the frame system buildings, widely used in the world, among which, the frame system made of STWS is particularly popular (see Fig. 1). STWS frame consists of galvanized solid or perforated profiles: guides, racks and bridges. For joining cold-folded profiles the following is used: 1) bolts (diameters from 5 to 16 mm); 2) self-tapping screws; 3) extruding rivets; 4) pneumatic and assembly dowels; 5) press-connections and so on. The fencing is represented by a construction of sheets assembly, which includes: insulation, facing sheets and vapor barrier films. The foundation can be a monolithic slab of shallow laying, piles or screw foundations. The use of such construct helps to reduce the time of building and simplify the construction process. The high thermal properties of buildings’ fences are also worth noting. The term of the construction of the buildings from the STWS is 4–5 months, which makes problematic the rapid deployment of medical complexes in emergency situations, however, it allows to set up a medical facility in remote areas where there is no hospitals and feldsher-midwife stations (hereafter FAP). Besides, this type of buildings makes it easy to organize a complex architectural group, which allows ease distribution of flows within a building, as well as to separate clean and dirty premises by sealing certain types of premises (depending on the function assigned).

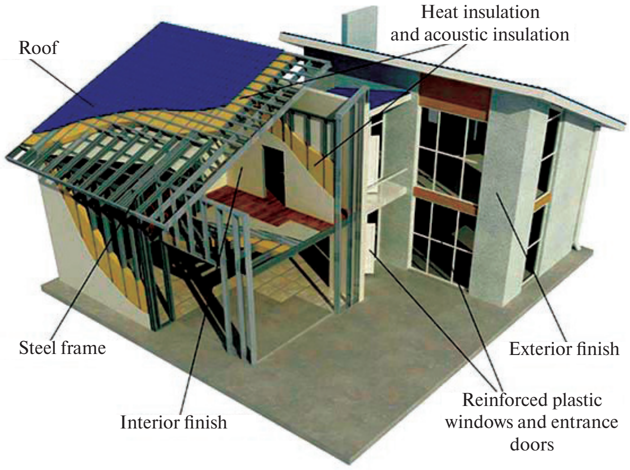

Fig. 1. Light-weight steel thin-walled structures [11]

Despite the advantages of this type of building, it should be noted that they can not be widely used in medicine, as not all medical processes can be implemented using the STWS. For example, when designing a hospital or temporary patient stays, and especially 24-hour chambers of different purposes, the building is assigned the highest category of both a medical facility and a fire hazard class, and the main flaw of this type of buildings is insufficient fire resistance in the absence of additional protection of structures. At the same time, the introduction of additional measures for fire protection of structures leads to a sharp rise in price, as well as a significant increase in both the construction time and the weight per a square meter. Installation of all structures, as well as the design of buildings should be done by highly qualified specialists, otherwise it could lead to the destruction of the building.

Frame-panel system buildings

The advantages of this type of structures are: 1) speed of construction (from 4 to 6 weeks thanks to a well-established and automated shields and beams manufacturing process); 2) light weight of the constructions; 3) easy installation; 4) no shrinkage (contrary to traditional construction); 5) high thermal insulation properties with low thickness of the walls. An important indicator of suitability can also be the geographical factor: in the regions with developed woodworking industry and the lack of metals (high cost of shipment of metal structures).

The main design of such buildings is a “spine-rib” construction with pre-calculated geometrical parameters of construction elements. The outer wall is represented by three-layer structure — a pre-fabricated on production site shield. Outside, the shield is covered with pergamon, the wall is filled with a heater (usually a mineral wool), in conclusion everything is covered with a vapor barrier, which can be the pergamon again. As for the thermal engineering properties, this wall construction of 180–300 thickness is comparable with a brick wall of 1,5 m thick. Any material (siding, lining, cement-shave slabs etc.) can be used for finishing, which is an advantage for this type PB.

However, the wooden frame-panel structures (see Fig. 2) significantly coincide to the STWS in many respects. The big disadvantage is low fire resistance of structures of these buildings. Its indicator is significantly inferior to other types, which imposes restrictions on using this technology that could be organized indoors. In addition, it is worth noting the reduction in environmental friendliness due to the use of synthetic materials in the wall.

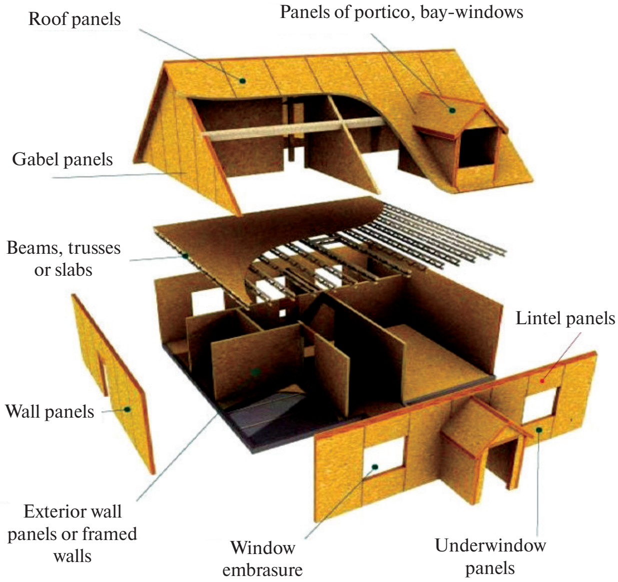

Fig. 2. Wooden frame-shield system [12]

In connection with foregoing this type of PB is not suitable for using as the premises for wide range of medical technologies. The arrangement of operational facilities is also impossible, since the supporting frame of the building and the enclosing structures are susceptible to increased bactericidal effects, as well as purulent and exudate absorption, which is not permissible, since the operating unit must have a special class of purity. Still, this type of PB can be used as a pharmacy or a temporary facility for FAP, temporary medical units of short purposes, as well as emergency medical services (an ambulance or emergency room).

Folding sections buildings

The building made of folding sections of shield type are complete, fully prefabricated buildings that have a collapsible structure that can be transformed during installation (see Fig. 3, 4). Generally, these buildings are made of lightweight metal structures that are delivered to the construction site in assembled form with factory readiness of up to 70 %. They consist of folding sections with installed wall and roof prefabricated panels, window frames, door binders, gates, end shields and additional elements.

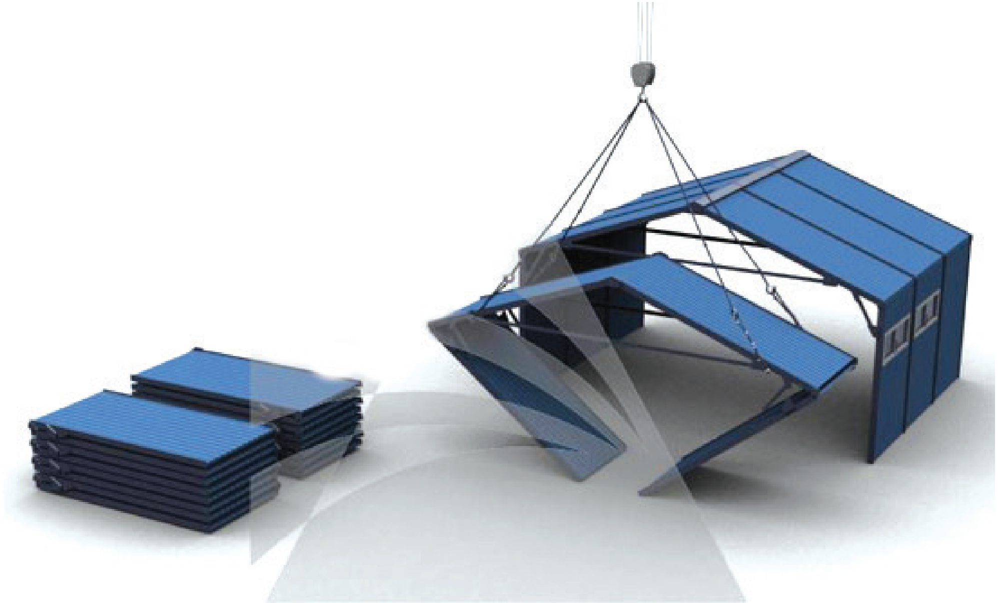

Fig. 3. Schematic diagram [13]

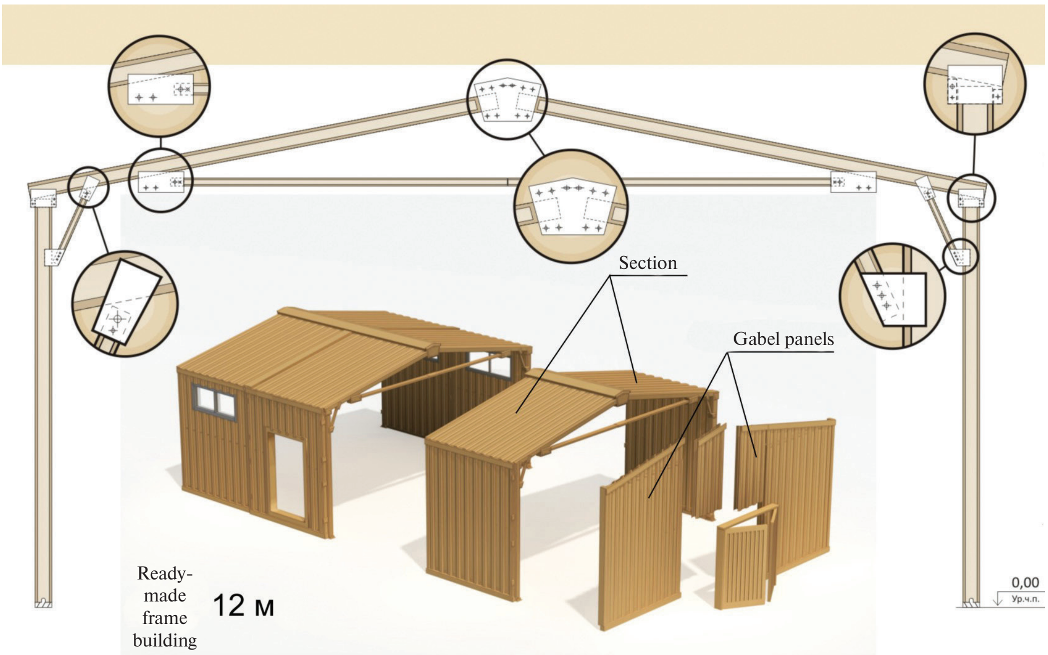

Fig. 4. Design solution [14]

An important advantage of this type of PB is that the load-bearing structures (the frame of the building) are part of its fencing, which reduces the metal content of structures. Insulated panels can be used at ambient temperatures below –50 °C. The longitudinal rigidity of the building is provided by the rigidity of the framework and profiled sheets. End walls ("deaf" or with a gate) are made of the end shields. Shields sections (wall and roofing) and end shields consist of sheathing (profiled sheet), mineral wool insulation and frame. The frame of panels is made of steel C-shaped profiles and channels. The outer and inner shields' sheathing represents a profiled metal sheet with trapeziodal shape of corrugation. The middle thermal insulation layer is a mineral wool board in a polyethylene film. Sections and end panels are installed on the supports welded to the foundations. The sections are joined by bolts. Span width is from 9 to 24 m. The advantages of such buildings include simplicity of installation, which does not require special qualification of installers, quick-release connections, high seismic resistance and the possibility of use in different climatic regions.

The disadvantage is the lower sealing capacity of premises (compared to other PB) due to the purging of joints. As a consequence, it is difficult to organize a single temperature regime, as well as air exchange and normalize laminar flows, which are important for the normal functioning of medical processes.

Based on advantages and disadvantages of PB we can determine the options of using these buildings for following possible medical: storage facilities (warehouses), temporary fixed points, hangars for storage of medical equipment and vehicles, temporary emergency rooms. For some functions, it is possible to arrange separate modules in the form of built-in premises. These modules (clean rooms, containers, etc.) make it possible to create functional areas within the general structure, as well as to provide the necessary sealing for certain types of premises and correctly organize laminar air flows. The use of additional modules will expand the sufficiently low functional suitability of this type of PB for medicine.

Frame-tent type buildings

Structurally frame-tent structures are not similar to any of the mentioned above. A single-layer or two-layer tent is a protective shell (membrane type), which is supported by a light frame made of aluminum, fiberglass, or polyethylene pipes (see Fig. 5). Such structures are very convenient for transportation. Their installation does not require special qualification of workers, since their assembly is extremely simple. The whole assembly takes 5–10 days for buildings of 12×72 meters. The range of normal operating temperatures of such premises is from –50 °C to +50 °C, which allows using them both in the Far North and in desert conditions. In the framework of such a shell there can be quick-release connections, and in the fabric basis — special "fastening" devices, which allows the transport of the shell in separate sections. The main advantages of such buildings are: high mobility (quick installation and dismantling); low metal consumption; translucence (does not require additional lighting during daylight hours); simplicity of assembly; constructive flexibility (possibility of modification of existing structures); low weight of structures.

Unlike other types of PB, it is advisable to use this type mainly as a domestic premise or a warehouse room, as well as a hiding place from the environment impact which makes this type related to buildings made of folding sections.

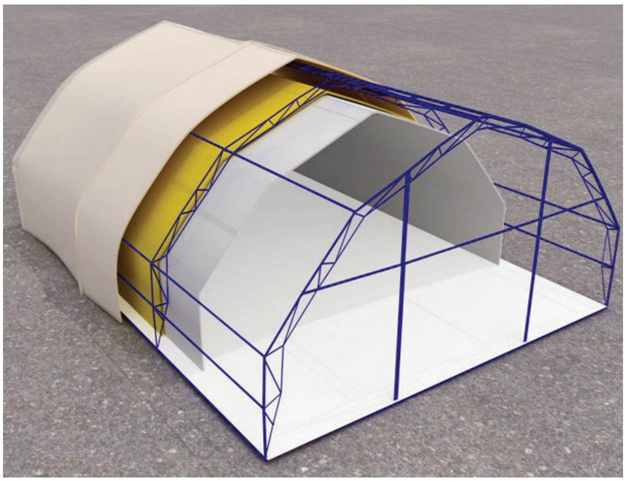

Fig. 5. Insulated two-membrane frame-tent structure [15]

However, these building have a number of inconviniences that are critical for medical technology: a short service life; high heat losses (higher than for PB from folding structures); susceptibility to vandalism; the dependence on climatic conditions due to the low value of the thermal inertia of the fencing.

A large number of factors that lead to the unfitness of this type of facility for a wide range of medical functions make it possible to clearly understand the inapplicability of this type for ambulatoric polyclinic medical centers. Nevertheless, this type is suitable for rapidly deployable temporary hospitals in special areas, some storage facilities or as a garage cover for ambulances.

Block-modular buildings. Container type buildings

This type of PB (see Fig. 6) has a wide range of application, including the medical technology. They can be easily moved and are manufactured in two forms: mobile and non-mobile. Structurally, they consist of a supporting frame and fencing. The framework has certain dimensions, which makes it possible to build structures of certain configurations and sizes. The fencing represents wall structures similar to sandwich panels. There is a load-bearing rigidity frame inside the enclosing structure. During manufacturing at the plant, all vital engineering communications are assembled at the stage of assembly of this module. Openings for windows and doors are also pre-installed, which leads to the ease of installation.

Fig. 6. Medical module (container) at the manufacturing site

An important advantage of this type of PB is that medical modules can be immediately equipped with the necessary equipment, furniture and plumbing. Low-flow-rate systems, as well as water main lines are installed in advance in the ceiling space. At the installation place all systems are connected to prepared outputs. The installation itself of the module can take 1 day and for about a week life support systems are being assembled. A module can be installed on any prepared surface (solid leveled surface — rocky ground; monolithic plate; strip foundation; block foundation; base of hollow plates, etc.) It takes 6 months from order to full readiness of the module at the plant. The fabricated modules meet all fire protection and sanitary requirements. A Medical Center with any technology and category of purity can be created on their basis. Such modules can create an excellent ensemble of technological units of a medical institution. A good example is the building of "UMMC Medicine — the Department of MRI" (an attached department) or "Cardiology Center in Chelyabinsk" (a complex building). When delivered to the customer, these modules are often issued as medical equipment, which reduces the cost of customs duties. These designs can be included in the category of medical equipment due to the possibility of complete installation with appropriate equipment, their repeatable use and the possibility of transportation by any suitable transport.

However, even such a universal solution has its flaws. Docking modules, as well as the subsequent maintenance of finishing works and work on connection of networks requires special preparation, which requires plant workers to train the staff. In addition, there is a decrease in the thermal insulation properties of the enclosing structures after several years of operation. It is also undesirable to use container modules in regions with high humidity and with constant low temperatures. Nevertheless, this is the most optimal option for medical institutions since they have the greatest compliance with sanitary, technical and fire-fighting standards.

Morphological analysis

To systemize the parameters of PB and the features of their use for medical technologies, a morphological analysis was performed, the results were tabulated (see table below).

Morphological analysis

No	Parameters	PB types				
		LSTK	Frame-shield	Folding sections	Frame-tent method	Container type
1	Versatility for medical technology	+	–	–	–	+
2	Providing sterility/Organization of a high class of cleanliness of the premise	+	–	–	–	+
3	Stability of the temperature mode	+	+	–	–	+
4	Impermeability of the initial construction	+	+	–	–	+
5	Flexibility of interior space	–	–	+	+	–
6	No need in retrofitting of an initial building	+	+	–	–	+
7	Fireproof security	+	–	+	–	+
8	High factory readiness	–	–	+	+	+
9	Construction speed	–	–	+	+	+
10	Possibility of re-transportation	–	–	+	+	+
11	Transportation convenience	–	–	+	+	+
12	Need in qualified staff during assembly	–	–	+	+	–
13	Construction cost	–	+	–	+	–
14	Variability of climatic performance	–	–	+	+	+
15	Possibility of use in seismic areas	–	–	+	+	+
Total of positive aspects		6	4	9	10	12

Conclusions

1. Based on the study results, a table with morphological analysis was compiled.

2. The most suitable type for incorporating the medical technological processes in the building is the container type of PB. It is also possible, under certain conditions, to use the frame-tent method and buildings from the folding sections.

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